SIZING OF A PHOTOVOLTAIC SYSTEM WITH BATTERY STORAGE: INFLUENCE OF THE LOAD PROFILE

J. Meunier[1,2]; D. Knittel[1,2]; P. Collet[3], G. Sturtzer[2], C. Carpentier[4], G. Rocchia[4], J. Wisse[5], M. Helfter[6]

1: University of Strasbourg, UFR Physique, 3 rue de l'Université, 67000 Strasbourg, France

2: INSA Strasbourg, LGeCo, 24 boulevard de la Victoire, 67084 Strasbourg, France

3: UFR Mathématiques et Informatique, 7 rue R. Descartes, 67084 Strasbourg, France

4: SOCOMEC, rue de Westhouse, 67235 Benfeld, France

5:VOLTEC Solar and VOLTINOV, 1 rue des prés, 67190 Dinsheim-sur-Bruche, France

6: HAGER Electro SAS, boulevard d'Europe, BP3, 67215 Obernai, France

Corresponding author: dominique.knittel@unistra.fr

ABSTRACT

Sizing of an optimal photovoltaic system includes constraints, fitness functions and parameters, which will have more and more importance in the next future: location (and panels direction), autonomy (which is the ratio of the consumed energy covered by the own production), self-consumption (ratio of the produced energy which is consumed by the building), investment capacity, price of the electricity (to buy, to sell), … This sizing depends on the global consumption of the building but also on the associated load profile. For the studied examples, the different load profiles are from the *"Standardlastprofile des Bundesverbandes der Energie- und Wasserwirtschaf", Germany*. The photovoltaic production profile is scaled from a measured production in the Rhine Valley, 2013. The consumption is carried out either by the grid or the battery, and the solar production supplies either the battery or the grid. In the studied application, the battery can only be charged by the photovoltaic energy.

The self-consumption, autonomy and bought electricity are calculated for different PV-storage systems and load profiles. The calculation software has been established in the Matlab environment. In order to obtain significant results, the simulations are conducted over a twenty-six-year period time. The results are analyzed and discussed. For a given configuration, load profile changes may lead to significant self-consumption and autonomy variations.

Keywords: photovoltaic, battery storage, sizing, simulation

INTRODUCTION

With a growing energy demand, renewable energies offer a way to provide energy without draining limited natural resources. But photovoltaic energy is intermittent. To supply at a best level a domestic electricity demand, where the consumption profile differs from the production, there is a need to store the daylight energy production. To satisfy this requirement, batteries are usually used [2, 3, 5]. But the size of the photovoltaic installation (i.e. total PV panel surface) and the size/number of the batteries should be optimized [2, 3, 4, 5, 6, 7, 8, 9, 10].

In this work, a photovoltaic system with batteries is modelled. The influence of different load profiles is then analyzed. The goal is to show that the load profile (and not only the maximum and the average values) has to be taken into account in the optimal sizing of the installation.

METHOD

Simulation model

The modelling software of the photovoltaic system including battery storage, programmed in the Matlab environment, requires electrical load profiles. In this study, the profiles data are from [1], all with a 5000 kWh/year consumption; whereas the photovoltaic production data comes from the Rhine Valley, 2013. All the data have a sampling time of 15 minutes. The studied system uses some photovoltaic panels with a decreasing efficiency of 0.5 % per year and lithium batteries to store the energy. These batteries have a maximum depth of discharge of 75 %, an efficiency of 90 % over a cycle and self-discharge of 1.5 % per day. The different consumption profiles are given below:

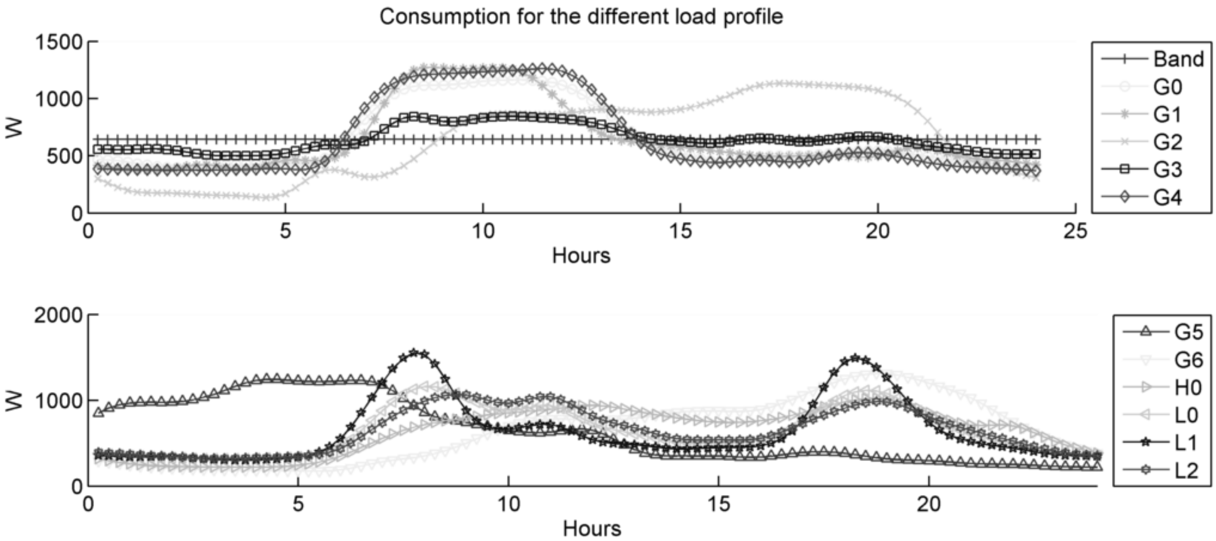

Figure 1: load profiles

Consumption profiles: Band (constant); G0 (Standard commercial); G1 (Commercial weekdays from 8 to 18 hours); G2 (Commercial with severe to predominant consumption in the evenings); G3 (Commercial continuously); G4 (Hairdresser); G5 (Bakery); G6 (Weekend operation); H0 (Household); L0 (Farms); L1 (Farms with sideline animal breeding/ dairy cattle); L2 (Farms without dairy cattle)

The used economic values are realistic values. The installation costs are: 1600 €/kWp for PV panels, 1670 €/kWh for battery storage. Moreover, the power electronic is changed after 13 years with of price of 300 €/kVA. The bought electricity price is 28 cts €/kWh with a rise of 4 % per year and a maximum of 50 cts €/kWh. The sold electricity price is 12.5 cts €/kWh with a lessening of 3 % per year and a minimum of 5 cts €/kWh. The grid subscription is 72 €/kW based on the maximum power required from the grid.

The simulation is conducted over 26 years (25 years warranty period of the PV panels +1 year). For each step time, the load energy is supplied either directly by the photovoltaic panels or by the batteries or by the grid as follow: the solar production is used to supply the load, then to fill the batteries until its maximum state of charge and finally to feed the grid. The batteries are used to supply the load while it is possible (the minimum state of charge has not to be undercrossed); finally the grid supplies the load.

Criteria : six criteria are used in this study:

- Self-consumption: ratio between produced energy and locally consumed energy (directly by the load or indirectly through the battery to the load). It is calculated over one year and only the first year is plotted.
- Autonomy: ratio between the needed energy and the part of the produced energy that is used locally. It is calculated over one year and only the first year is plotted.
- ROI (Return on investment): number of years for which the cumulated expenses of the PV installation is equal to the cumulated expenses for no installation.
- Number of battery cycles after 26 years (the batteries have 6000 cycles of lifetime).
- Investment: initial cost of an installation depending on the number of photovoltaic panels and the number of batteries.
- Cumulative expenses after 26 years.

RESULTS

The next figures show the six criteria for 3 configurations: 3 kWp of photovoltaic system without any battery (figures 2-3), 3 kWp of photovoltaic system with 3 kWh battery storage (figures 4-5) and 3 kWp of photovoltaic system with 6 kWh battery storage (figures 6-7).

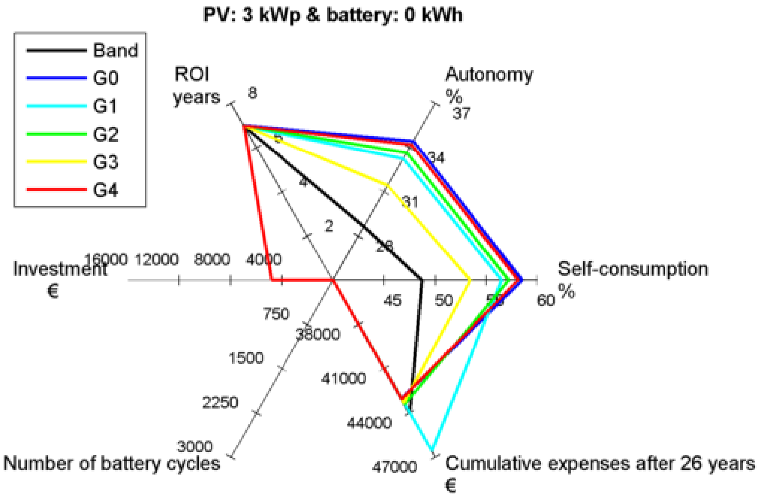

Figure 2: Results for 3kWp- PV, no battery

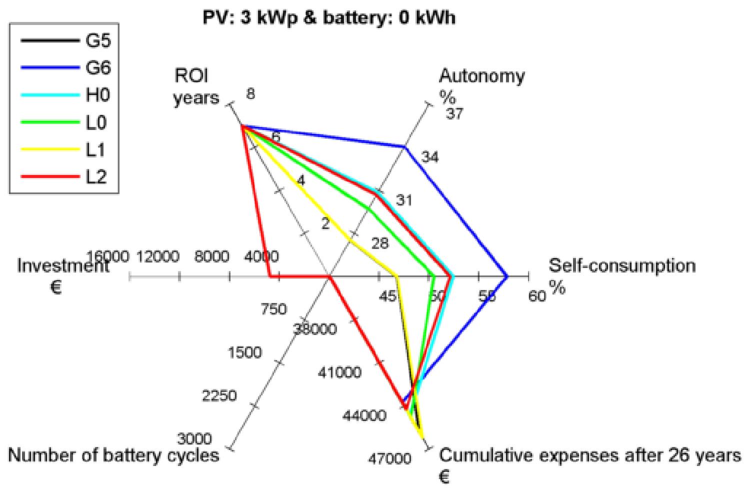

Figure 3: Results for 3kWp- PV, no battery

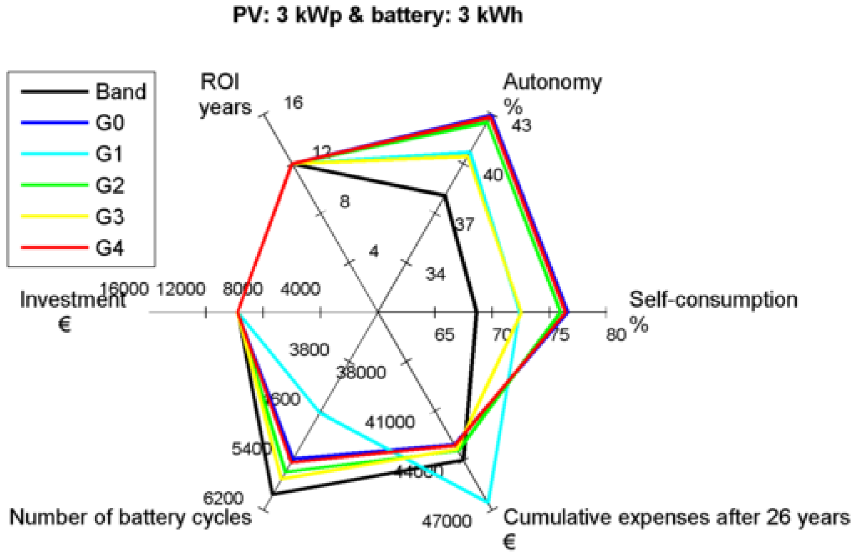

Figure 4: Results for 3kWp- PV, 3 KWh-batteries

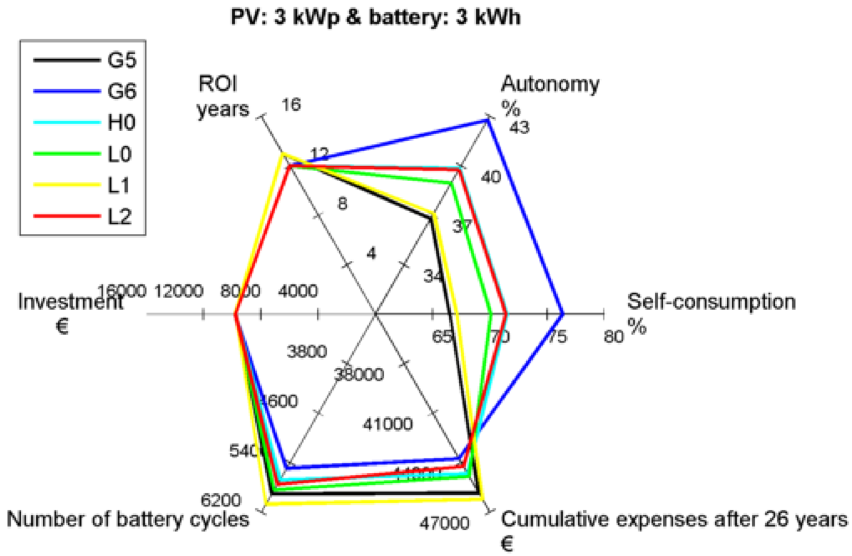

Figure 5: Results for 3kWp- PV, 3 KWh-batteries

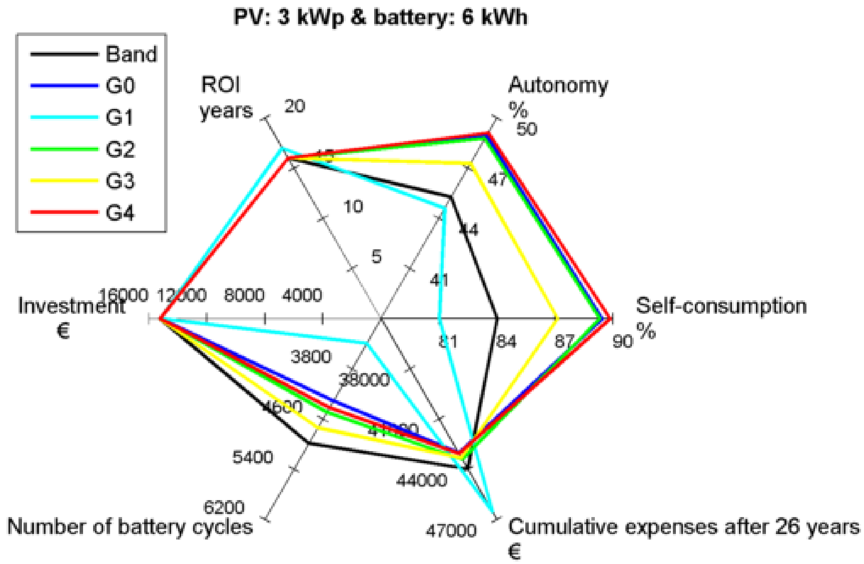

Figure 6: Results for 3kWp- PV, 6 KWh-batteries

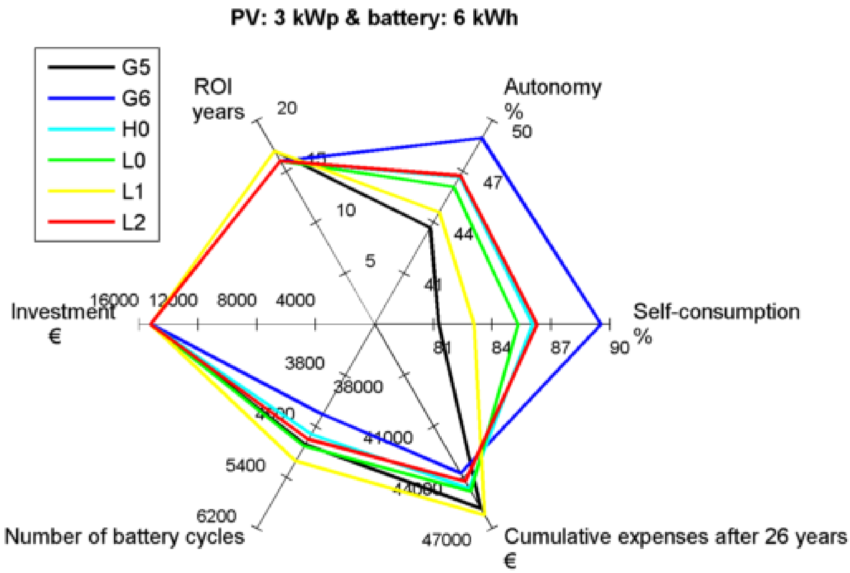

Figure 7: Results for 3kWp- PV, 6 KWh-batteries

DISCUSSION

Configuration 1 : 3 kWp of photovoltaic system without any battery (figures 2-3):

all profiles lead to the same ROI and investment. The cumulative expenses (after 26 years) are quite similar. But there are significant autonomy and self-consumption variations, especially for the band and L1 profiles.

Configuration 2 : 3 kWp of photovoltaic system with 3 kWh battery storage (figures 4-5):

all profiles lead to the same investment, a similar ROI (maximum 1 year difference) and similar cumulative expenses after 26 years. Moreover, the number of battery cycles presents small variations. But there is a wider spreading of the autonomy and self-consumption.

Configuration 3 : 3 kWp of photovoltaic system with 6 kWh battery storage (figures 6-7):

all profiles give the same investment, a similar ROI (maximum 1 year difference) and similar cumulative expenses after 26 years. Moreover, the number of battery cycles presents small variations (except for the profile G1). There are large autonomy and self-consumption variations.

Comparison between the 3 configurations:

- ROI: as expected, the lowest ROI is obtained for configuration 1 and the configuration 3 gives the highest ROI.
- Cumulative expenses after 26 years : quite similar for the 3 cases
- Investment : highest investment obtained for configuration 3
- Number of battery cycles after 26 years : highest value obtained for configuration 2
- Autonomy: highest value obtained for configuration 3
- Self-consumption: highest value obtained for configuration 3

CONCLUSION

This work shows that the load profiles (and not only the maximum or average consumption) play a significant role in different criteria used for PV installation with batteries optimization. For a given configuration, load profile changes may lead to significant self-consumption, autonomy and number of battery cycles variations. But the different profiles lead to small ROI variations (maximum one year of difference).

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